

# The study of the relationship between stock value and financial performance of iron and steel enterprises using artificial intelligence techniques

V V Potanin<sup>1,2</sup> and O Yu Sidorov<sup>1</sup>

<sup>1</sup> Ural Federal University named after the First President of Russia B N Yeltsin, Nizhniy Tagil Technological Institute, 59, Krasnogvardeyskaya str., Nizhniy Tagil, 622000, Russia

E-mail: <sup>2</sup> v.v.potanin@urfu.ru

**Abstract.** Study of the relationship between finance performance and market equity value of Russian public companies, such as PJSC Mechel, PJSC Novolipetsk Iron and Steel Works, PJSC Magnitogorsk Iron and Steel Works, PJSC Severstal using the artificial neural network (ANN) has been carried out. Data of annual financial statements, stock-exchange equity prices, USD/RUB, EUR/USD exchange rates, RF CB base rate were used as initial data. The number of instructional examples was equal to 15 and there were 16 input values included into each example. In the end, ANN calculated the ratio of the market value of one share to equity capital per share. ANN training was carried out using the backpropagation method and the conjugate gradient method. The average values of discrepancies between the actual value of the ratio of market value to equity capital and calculated value using ANN were 6.0, 2.5, 8.2 % for NLMK, Severstal and MMK, respectively. The use of ANN has shown the overestimated value of equity stock-exchange quotations of PJSC Mechel in relation to the market averages.

## 1. Introduction

The use of artificial neural networks (ANNs) is especially reasonable in case when the studied value depends on myriad of factors and this dependence is implicit and stochastic. This is often demonstrated when studying financial and economic phenomena.

The paper [1] considers the possibility of using ANN and semantic analysis to predict the corporate bankruptcy based on its annual financial statements.

The paper [2] introduces the possibility for prediction of financial time-series using combined ANN with layers of different types. The paper shows [3] that trade strategies based on the classification models of ANNs generate higher profit than buy-and-hold strategies. The paper [4] uses the recurrent neural network for prediction of stock international market indexes. A neural network model was used in papers [5–7] to predict stock value, stock market trends, and relationships with technical analysis using Japanese candlesticks.

The ability of ANN to predict daily quotations of NASDAQ stock exchange index for two types of input data was investigated in the study [8]: four previous days and nine previous days. The paper [9] analyses the neural network model which predicts the highest Sharpe ratio of investment portfolio.

The paper [10] presents the effects of four types of ANN for prediction of common-stock value. It has been noted that the convolutional ANN was able to predict the values of New York Stock Exchange Index based on training with the use of values of India Stock Exchange Index.



The ability of ANN to predict Gazprom stock prices (5-minute data) and Sberbank shares (daily data) was checked in the studies [11, 12]. The significant differences between predicted and actual values [11] were obtained in some cases for Gazprom shares. Acceptability of the obtained results was noted for Sberbank shares [12].

The paper [13] considers ANN for prediction of profitability of Finam Narodnyi hybrid unit investment trust. The possibility of correct prediction of the participation unit value trend and the impossibility of accurate prediction for the near-term tone of the participation unit value are noted.

The performed review shows the possibility and rationale of the studies regarding the use of neural network technologies to describe the financial and economic features of companies.

## 2. Problem statement and initial data

This paper aims at assessment of the market value of companies PJSC Mechel (Mechel) and JSC 'EVRAZ Nizhniy Tagil Iron and Steel Works' (NTMK) using ANN based on annual statement data as well as assessment of the market value of companies PJSC Novolipetsk Iron and Steel Works (NLKM), PJSC Magnitogorsk Iron and Steel Works (MMK), PJSC Severstal (Severstal).

Data of accounting statements (balance sheet, profit and loss statement), shown on the web site [14–18] for 5 years (2014–2018) was selected as initial data. The exception is Mechel, for which complete data is available only for 2015–2018.

In addition, equity quotations and their number of companies NLKM, MMK, Severstal [19], data on the external economic environment were used as input data: RF CB base rate, USD/RUB and EUR/USD exchange rates [20]. The latest data were selected with a forward shift of 3 months, i.e. the beginning of April in the year following the reporting one. This is due to the fact that reporting is prepared later than the end of the reporting period.

The initial data were specified: consolidated balance sheet items were divided into balance sheet total (BST); aggregates of profit and loss statement were divided into income (I); external economic data was corrected to the interval (0; 1).

The specified initial data (instructional example) for NLKM for 2018 is given in Table 1 as an example.

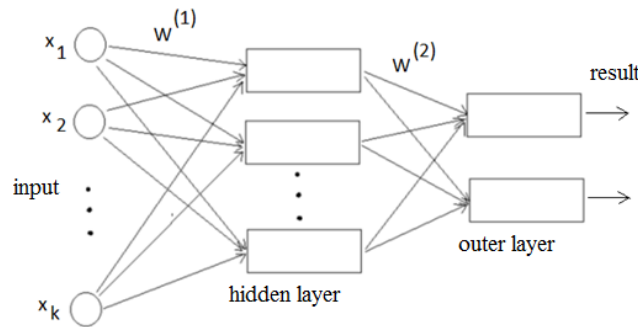
**Table 1.** Example of specified initial data (NLKM, according to the results of 2018).

No.	Input data for ANN	Value
1	Fixed assets/BST	0.0566
2	Current assets/BST	0.434
3	Capital and reserves/BST	0.581
4	Long-term liabilities/BST	0.0164
5	Short-term liabilities/BST	0.255
6	Initial cost/I	−0.671
7	Gross profit/I	0.0329
8	Sales profit/I	0.023
9	Profit before tax/I	0.0276
10	Net profit/I	0.0239
11	Profit before tax per share	0.02276
12	Equity capital per share (EC1)	0.05608
13	USD/RUB	0.654176
14	EUR/USD	0.11235
15	RF CB base rate	0.0775
16	Output target value for ANN: Market stock value/EC1	0.312

The number of instructional examples was equal to 15 and 16 input values (a set of training data contained 240 values) were included into each example. In the end, ANN calculated the ratio of the market value of one share to equity capital per share.

### 3. ANN description and its training

Artificial neural network (ANN), the structure of which is given in Figure 1, was used for simulation. Logistic function was used as compressive function [21]. The number of neurons in the hidden layer was selected to be equal to 15, and in the outer layer – 2 (one neuron was backup).



**Figure 1.** ANN structure.

For ANN training the backpropagation method was used (see, for example, [21]), within the framework of which functionality of type was minimized

$$E(w) = \frac{1}{2} \sum_{t=1}^T \sum_{l=1}^n (y_{lt} - d_{lt})^2 \rightarrow \min$$

where  $T$  – number of instructional examples, which the given result  $d_{lt}$  corresponds to (these are the values of the Market stock value/EC1 – see Table 1);  $n$  – number of neurons in the output layer ( $n = 2$ );  $y_{lt}$  – egress of neural network during the training.

Minimization parameters were weight matrices  $w^{(1)}$  and  $w^{(2)}$ . The searching of elements of neural network weight matrices was carried out using the conjugate gradient method (see, for example, [22]). Within the framework of this approach it is necessary to determine the partial derivatives of the functionality  $E(w)$  with respect to the elements of weight matrices  $w_{ij}^{(1)}$  and  $w_{ij}^{(2)}$ . The following was obtained

$$\frac{\partial E}{\partial w_{jk}^{(2)}} = \sum_{t=1}^T (y_{kt}^{(2)} - d_{kt}) \cdot (1 - F(S_{kt}^{(2)})) \cdot F(S_{kt}^{(2)}) \cdot y_{jt}^{(1)}, \quad j = 1 \dots n, \quad k = 1 \dots p \quad (1)$$

$$\frac{\partial E}{\partial w_{ij}^{(1)}} = \sum_{t=1}^T \sum_{l=1}^p (y_{lt}^{(2)} - d_{lt}) \cdot (1 - F(S_{lt}^{(2)})) \cdot F(S_{lt}^{(2)}) \cdot (1 - F(S_{jt}^{(1)})) \cdot F(S_{jt}^{(1)}) \cdot x_{it} \cdot w_{jl}^{(2)} \quad (2)$$

$i = 1 \dots m, \quad j = 1 \dots n$

Here, the following designations were used

$$S_{jt}^{(1)} = \sum_{i=1}^m x_{it} \cdot w_{ij}^{(1)}, \quad j = 1 \dots n; \quad y_{jt}^{(1)} = F(S_{jt}^{(1)}) = F\left(\sum_{i=1}^m x_{it} \cdot w_{ij}^{(1)}\right)$$

$$S_{lt}^{(2)} = \sum_{j=1}^n y_{jt}^{(1)} \cdot w_{jl}^{(2)}, \quad l = 1 \dots p; \quad y_{lt}^{(2)} = F(S_{lt}^{(2)}) = F\left(\sum_{j=1}^n y_{jt}^{(1)} \cdot w_{jl}^{(2)}\right)$$

Formulas (1)–(2) determine the partial derivatives of the objective function  $E(w)$  on the weight of neurons of the second (outer) and first (hidden) layers.

The following calculations were carried out within the framework of the conjugate gradient method [22]:

- set  $x_0$  and calculate  $p_0 = -g_0$  at the first step;
- calculate  $p_k = -g_k + \beta_k \cdot p_{k-1}$ ,  $\beta_k = \frac{\|g_k\|}{\|g_{k-1}\|}$ ,  $x_k = x_{k-1} + \eta \cdot p_k$  at the step  $k$ .

Where  $g_k$  – gradient vector, the components of which are determined by formulae (1) and (2);

$x_k$  – vector, containing values of the elements of weight matrices  $w_{ij}^{(1)}$  and  $w_{ij}^{(2)}$ ;  $\eta$  – parameter.

The calculations are completed if vector components  $g_k$  become less than the specified accuracy of calculations. The result of using ANN is expressed with the following scheme

$$(x_1 \quad \dots \quad x_m) \cdot w^{(1)} \rightarrow \begin{pmatrix} F(S_1^{(1)}) \\ \vdots \\ F(S_n^{(1)}) \end{pmatrix} = \begin{pmatrix} y_1^{(1)} \\ \vdots \\ y_n^{(1)} \end{pmatrix} \rightarrow (y_1^{(1)} \quad \dots \quad y_n^{(1)}) \cdot w^{(2)} \rightarrow \begin{pmatrix} F(S_1^{(2)}) \\ \vdots \\ F(S_p^{(2)}) \end{pmatrix} = \begin{pmatrix} y_1^{(2)} \\ \vdots \\ y_p^{(2)} \end{pmatrix}$$

ANN training was carried out with an allowable error of 0.00001 and was equal to 204,744 iterations of the conjugate gradient method.

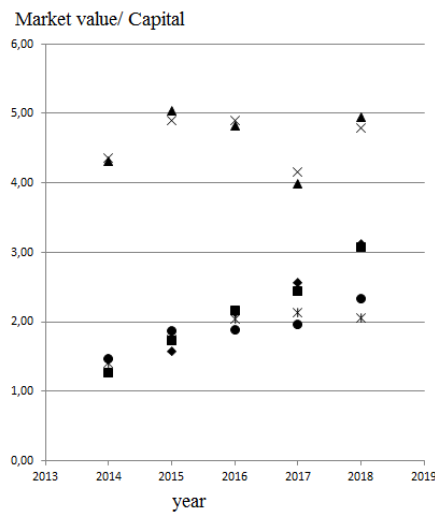
#### 4. Results and discussion

Figure 2 shows the results of ANN training, at which designation ‘Market value/Capital’ characterizes the ratio of the market value (according to data of stock trading) to equity capital (‘Capital and reserves’ indicator according to data of balance sheet). The average values of discrepancies between the actual value of MV/EC and calculated value by means of ANN were 6.0, 2.5, 8.2 % for NLMK, Severstal and MMK, respectively.

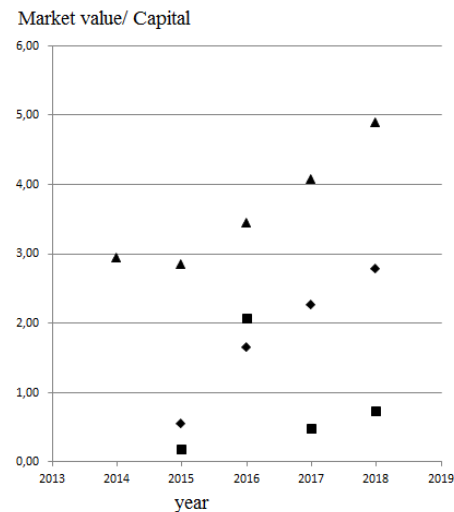
The trained ANN will be used for assessment of market indicators of the companies in the same industry (ferrous metallurgy) – NTMK and Mechel. It should be noted that NTMK shares are not listed at stock exchanges; therefore, calculation of its market value can be carried out through the involvement of ANN trained according to the analogue companies. The accounting statement analysis [17] of Mechel company shows its spotty economic status, therefore, the assessment of its market value using the trained ANN brings us to the conclusion on conformity of Mechel equity stock-exchange quotations to the same values for NLMK, Severstal, MMK.

Calculation results shown in Figure 3 indicate that the MV/EC indicator for NTMK is in the range of 2.86–4.90. The calculated (ANN) and actual indicators of MV/EC for Mechel (Figure 3) are substantially different from each other, especially for 2017 and 2018. This brings us to the conclusion that the level of Mechel equity stock-exchange quotations in this period is overestimated in relation to the market averages.

Figure 4 shows the actual market values of NLMK, Severstal and MMK enterprises, as well as the market values of NTMK calculated using ANN. These data bring us to the conclusion that NTMK is at the level of leading iron and steel enterprises of the Russian Federation according to the economic indicators.

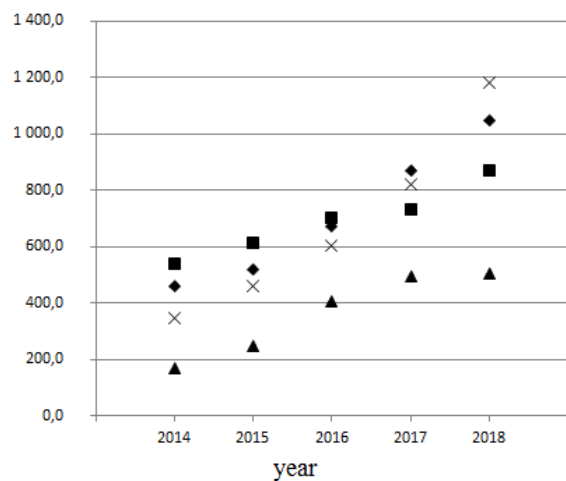


**Figure 2.** Results of ANN training: rhomb, square are actual values and results of ANN for NLMK; triangles, dashes are actual values and results of ANN for Severstal; asterisks, circles are actual values and results of ANN for MMK.



**Figure 3.** Actual values and calculation results. Triangles are calculation for NTMK using ANN; rhombs, squares are actual values and results of ANN for Mechel

Market value, billion rub.



**Figure 4.** Market value change trends. Rhombs, squares, triangles are actual data for NLMK, Severstal, MMK, respectively; dashes are calculated values for NTMK, obtained using ANN.

## 5. Conclusions

1. The artificial neural network for assessment of the market value of iron and steel enterprises of the Russian Federation has been composed.
2. The use of artificial neural network brings us to the conclusion that the level of equity stock-exchange quotations of PJSC Mechel is overestimated in relation to the market averages within the period of 2017–2018.
3. The calculated market values of JSC ‘EVRAZ Nizhniy Tagil Iron and Steel Works’ indicate that the company is at the level of leading iron and steel enterprises of the Russian Federation according to the economic indicators.

The calculations were performed with the program in C#.

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